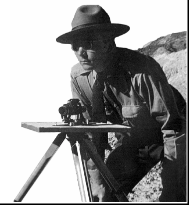
GEOLOGIC RESOURCE MONITORING PARAMETERS

Volcanic Unrest



Brief Description: Eruptions are almost always preceded and accompanied by volcanic unrest, indicated by variations in the geophysical and geochemical state of the volcanic system. Such geoindicators commonly include changes in seismicity, ground deformation, nature and emission rate of volcanic gases, fumarole and/or ground temperature, and gravity and magnetic fields. Volcanic unrest can also be expressed by changes in temperature, composition, and level of crater lakes, and by anomalous melting or volume changes of glaciers and snow fields on volcanoes. When combined with geological mapping and dating studies to reconstruct comprehensive eruptive histories of high-risk volcanoes, these geoindicators can help to reduce eruption-related hazards to life and property. However, not all volcanic unrest culminates in eruptions: in many cases the unrest results in a failed eruption in which the rising magma does not breach the surface and erupt.

Significance: Natural hazards associated with eruptions of the world's 550 or so historically active volcanoes pose a significant threat to about 10% of the world's population, especially in densely-populated circum-Pacific regions. By the year 2000, more than half a billion people will be at risk. Before 1900, two indirect hazards - volcanogenic tsunamis and post-eruption disease and starvation - accounted for most of the eruption-associated human fatalities. In the 20th century, however, direct hazards related to explosive eruptions (e.g. pyroclastic flows and surges, debris flows, mudflows) have been the most deadly hazards. Lava flows can cause great economic loss from property damage and decreased agricultural productivity, but they rarely cause deaths.

Environment where Applicable: Most active volcanic systems are located along or near divergent and convergent boundaries between the Earth's tectonic plates. However, some volcanoes (e.g. Hawaii) occur thousands of kilometers from the nearest plate boundary and result from melting and eruptive processes associated with the passage of a tectonic plate over a fixed thermal anomaly (or hotspot) in the mantle.

Types of Monitoring Sites: Geologically young volcanic regions containing active or potentially active volcanoes, subaerial or submarine (including the deep ocean floor). Diagnostic monitoring sites commonly include active vents and fumaroles, crater lakes, and areas of ground cracking. Ideally the sites should be distributed over the entire volcanic system, to monitor both the summit and flank areas of eruptive centers.

Method of Measurement: Optimum monitoring of volcanic unrest must be based on a combination of geophysical, geodetic and geochemical methods, rather than reliance on any single technique. These involve a networks of monitoring sites at key locations around a volcanic center at which repeated measurements are made of horizontal and vertical ground displacements (borehole strainmeter, laser distance measurements, gravimeter, tiltmeter, GPS observations), seismicity (automatic event recording, 3-component and broad band seismometry, and special array techniques), and a wide range of geochemical parameters.
Ground-based seismic and deformation monitoring approaches have proven to be the most reliable and diagnostic in early detection and tracking of volcanic unrest. In recent decades these two approaches have been augmented by volcanic-gas, microgravity, geomagnetic, and remote-sensing studies. Satellite-based methods are increasingly used for measuring ground displacements and variations in thermal and volatile output at volcanic centers. Experience worldwide shows that volcano surveillance is best accomplished by on-site volcanic observatories or nearby centralized facilities at which all of the monitoring data are collected, processed and interpreted by experienced multi-disciplinary scientific teams.

Frequency of Measurement: For frequently active volcanoes, measurement should be continuous. For potentially active volcanoes currently in repose, geophysical and geochemical baseline monitoring data should be obtained and then followed by repeat measurements every few years. However, after the recognition of possible departure from baseline behaviour, the monitoring networks should be expanded and measurements should be made on a more frequent, preferably continuous, basis.

Limitations of Data and Monitoring: The paramount limitation in detecting and tracking volcanic unrest is simply that no more than a small percent of the world's volcanoes are now being monitored. An overwhelming majority of the high-risk volcanoes are in developing countries that lack sufficient economic and scientific resources to conduct the necessary monitoring. Even in the richer nations, current efforts to reduce government expenditures are compromising the effectiveness of existing monitoring programs.

Possible Thresholds: With current knowledge and volcano-monitoring techniques, it is not yet possible to determine a fixed threshold value in the magnitude or duration of volcanic unrest, which, if exceeded, inexorably leads to eruptive activity. However, at a few well-monitored volcanoes, scientists are beginning to recognize patterns of build-up of precursory geoindicators that characterize magma movement and/or hydrothermal-pressurization effects at a given volcano.

Key References:

Ewert, J.J. & D.A.Swanson (eds) 1993. Monitoring volcanoes: techniques and strategies used by the staff of the Cascades Volcano Observatory 1980-1990. U.S. Geological Survey Bulletin 1966.

McGuire, B., C.R.J.Kilburn & J.Murray (eds) 1995. Monitoring active volcanoes: strategies, procedures and techniques. London: University College London Press.

Scarpa, R. & R.I.Tilling 1996. Monitoring and mitigation of volcano hazards. Berlin: Springer-Verlag.

Related Environmental and Geological Issues: Injections of volcanic ash and gases high into the atmosphere during explosive eruptions can have significant, and possibly global environmental effects. It is now well documented that large explosive eruptions that form stratospheric clouds of volcanic aerosols (e.g. Tambora, Indonesia, in 1815; El Chichon, Mexico, in 1982; and Mount Pinatubo, Philippines, in 1991) produce measurable effects on global climate, such as a hemispheric cooling of up to 0.5 C, that can persist for several years. In-flight encounters between jet aircraft and volcanic ash have recently emerged as a serious and growing volcanic hazard, as air traffic increases worldwide.

Overall Assessment: Early recognition and systematic monitoring of unrest in volcanic areas is essential. It can significantly mitigate eruption-related hazards by improving understanding of volcanic phenomena before, during and after eruptions, by refining long-term and short-term eruption-forecasting capability, and by providing the fundamental data for preparing hazard-zonation maps and for assessing volcano hazards.

Source: This summary of monitoring parameters has been adapted from the Geoindicator Checklist developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning. Geoindicators include 27 earth system processes and phenomena that are liable to change in less than a century in magnitude, direction, or rate to an extent that may be significant for environmental sustainability and ecological health. Geoindicators were developed as tools to assist in integrated assessments of natural environments and ecosystems, as well as for state-of-the-environment reporting. Some general references useful for many geoindicators are listed here:

Berger, A.R. & W.J.Iams (eds.) 1996. Geoindicators: assessing rapid environmental change in earth systems. Rotterdam: Balkema. The scientific and policy background to geoindicators, including the first formal publication of the geoindicator checklist.

Goudie, A. 1990. Geomorphological techniques. Second Edition. London: Allen & Unwin. A comprehensive review of techniques that have been employed in studies of drainage basins, rivers, hillslopes, glaciers and other landforms.

Gregory, K.J. & D.E.Walling (eds) 1987. Human activity and environmental processes. New York: John Wiley. Precipitation; hydrological, coastal and ocean processes; lacustrine systems; slopes and weathering;

river channels; permafrost; land subsidence; soil profiles, erosion and conservation; impacts on vegetation and animals; desertification.

Nuhfer, E.B., R.J.Proctor & P.H.Moser 1993. The citizens' guide to geologic hazards. American Institute for Professional Geologists (7828 Vance Drive, Ste 103, Arvada CO 80003, USA). A very useful summary of a wide range of natural hazards.